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Effect of internal recycling ratios on biomass parameters and simultaneous reduction of nitrogen and organic matter in a hybrid treatment system

Dinh Duc Nguyen[a,b,**], Huu Hao Ngo[c], Yong Soo Yoon[d,*]

[a] Ho Chi Minh City University of Natural Resources and Environment, Viet Nam
[b] Lotus Engineering Co., LTD, South Korea
[c] School of Civil and Environmental Engineering, Faculty of Engineering and Information Technology, University of Technology Sydney, Broadway, NSW 2007, Australia.
[d] Department of Chemical Engineering, Dankook University, 448-701, South Korea

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ABSTRACT

A new large-scale pilot hybrid treatment system of 53 m^3/day was developed by combining 3 treatment methods: switched internal recycling flows to equalization tank (EQ); rotating hanging media bioreactor (RHMBR); and submerged flat sheet membrane bioreactor (SMBR). The system was operated for more than 16 months in a real-world municipal wastewater treatment plant, using different internal recycling ratios and observing/monitoring the results. This paper addresses not only the urgent problems of treating nutrient and organic pollutants in municipal wastewater, but also assesses characteristics of biomass production, sludge yield, and observed yield during the pilot operation. It also details design parameters used to achieve these assessed levels. Furthermore, the effects and correlations of the loading rates, activated sludge and biomass parameters, on different runs were also studied. The purpose of this was to identify the most suitable indicator for assessing the hybrid system's performance. Results strongly indicated that increasing the internal circulation rate greatly influenced the declining yield trend. The lowest biomass production ($P_{x,bio}$) and sludge yields ($P_{X,VSS}$ or $P_{X,TSS}$) were shown for conditions in run 3, and run 4, respectively. Overall the developed treatment system performed extremely well in biological terms for actual municipal wastewater treatment and resulted in high pollutant removal efficiencies, reduced sludge production at a reasonable cost. The hybrid system is a potential option for wastewater treatment, reuse and economy.

1. Introduction

In recent years, biological wastewater treatment technologies using membranes (MBR) combined with biofilm support media have received special attention from many scientists worldwide. This is evident from the increased number of scientific research papers addressing this topic. Together with ongoing research, these technologies are increasingly being developed and widely applied in wastewater treatment systems in many countries, because they offer economic and technical advantages over conventional technology that is becoming obsolete (Cresson et al., 2006; Jou and Huang, 2003; Jurecska et al., 2013; Leiknes et al., 2006; Li et al., 2013; Martin and Nerenberg, 2012; Tarjányi-Szikora et al., 2013), including the chemical treatment processes (Fan et al., 2009). This information indicates that, despite showing immense potential for its application in the present and future, the problem of excessive sludge generation persists. The optimal parameters/values in the application of membrane technology are still limited, especially by biomass, or sludge generation, which remains an unwanted technological byproduct of these systems. Consequently, more effective methods of biomass management must be optimized through ongoing research.

The disposal of excess/residual sludge biomass from waste water treatment plants (WWTPs) is a matter of major concern (Kabir et al., 2011; Low and Chase, 1999; Semblante et al., 2014) and a very practical question, because it directly affects investment costs of sludge treatment processes such as sludge digester, sludge dewatering, etc. Several effective technologies currently minimize

* Corresponding author at: Dankook University, South Korea.
Tel.: (+82) 31 8005 3539; fax: (+82) 31 8021 7216.
** Corresponding author at: Ho Chi Minh City University of Natural Resources and Environment, Viet Nam.
E-mail addresses: nguyensyduc@gmail.com (D.D. Nguyen), chemyoon@unitel.co.kr (Y.S. Yoon).

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excess sludge production, namely: ultra-sonication (Khanal et al., 2007; Pilli et al., 2011), thermal treatment (Razmjoo and Sefidari, 2011), chemical treatment (Liu, 2003), etc. Alternative uses for excess sludge from municipal WWTPs have also proved to be beneficial in reuse, such as fertilizer in agriculture, and improving fertility of barren/infertile soils. However, that potential has inherent risks because many sources contain heavy metals, organic chemicals, viruses, etc. (Clarke and Smith, 2011; Harrison et al., 2006). In addition, people's need for clean water is continually increasing, and effluent wastewater quality requirements have become increasingly more stringent as a result. This also causes an increase in sludge waste (Low and Chase, 1999). Therefore, to reduce biomass produced from the WWTPs, designers and engineers should deploy a uniform solution from management, applied technology, and environmental engineering for real-world solutions. Implementing informed guidelines based on enlightened government policies is essential for successful wastewater sludge mitigation and treatment in the future. Thus, a solution is needed to reduce excess sludge production at the first source rather than seeking the technologies to mitigate it after the generation of unwanted by-products (Wang et al., 2009).

This investigation seeks to offer a better interpretation and evaluation of biomass production, sludge yield, observed yield, and the correlation between them, in a system that has been regarded as effective and flexible. Better understanding of such features of the process could also provide valuable information for optimizing the versatility and measurement conditions in sludge treatment unit designs, installation and operation.

In this paper, instead of proposing a uniform solution, we develop a method of managing an integrated approach for handling excess sludge. This approach was effective in handling simultaneous nutrient and organic matter. We further evaluated the influence of the internal recycle ratios in reducing excess sludge production, subsequently minimizing sludge yield, and also their effects on overall process performance. In addition, methods of predicting and estimating the amount of sludge produced every day are based on the newly determined internal recycle ratios. This allows reliable performance to be achieved, and hopefully more widespread application of the methods described herein.

2. Methods

2.1. Influent wastewater characteristics/components of influent wastewater

The wastewater quality data of the pilot plant influent was collected from the collection sump of a municipal wastewater treatment plant (WWTP) of 110,000 m^3/day, with characteristics within the range (average) of 175–460 (281.90) mg SS/L, 166.73–222.32 (205.76) mg BOD_5/L, 187.7–334.9 (238.83) mg COD_{Cr}/L, 30.83–63.08 (41.16) mg T–N/L, 0.00–1.06 (0.20) mg NO_3^-–N/L, 18.89–43.54 (29.85) mg NH_4^+–N/L, 2.51–6.95 (4.46) mg PO_4^{3-}–P/L and 3.00–8.39 (5.45) mg T–P/L.

Influent wastewater pH, Alkalinity (Alk.), and Coliform bacteria varied in a range of 7.0–8.0, 90–220, 1.5E + 6–2.0E + 7, respectively, during the study period.

2.2. Pilot plant and description

A general process flow schematic of the hybrid treatment system is provided in Fig. 1. The pilot plant apparatus and experiments for municipal wastewater treatment were conducted using a high density polyethylene (HDPE) paneling, polyethylene sheet lining, and then installed in a WWTP in Y City, South Korea. It combined an innovative equalization tank which integrates anoxic/anaerobic conditions using fiber polypropylene carriers in one reactor, and an aerobic membrane bioreactor (MBR), along with a submerged flat sheet membrane for solid–liquid separation. The experimental pilot plant system had a capacity of approximately 53 m^3/day (Fig. 1). The size and working volume of each compartment are shown in Table 1.

Raw wastewater from the municipal WWTP was successively pumped alternately by two automatic centrifugal pumps and passed through a fine screen (FS), with 5 mm openings, to the equalization tank (EQ). In the equalization tank, the concentration and flow of wastewater was balanced prior to the wastewater entering the anaerobic/anoxic tank (RHMBR) to initiate the denitrification process and alkalinity recovery. From there, a gravity assisted flow channeled the effluent to the membrane bioreactor (MBR) under aerobic conditions with high biomass concentration for

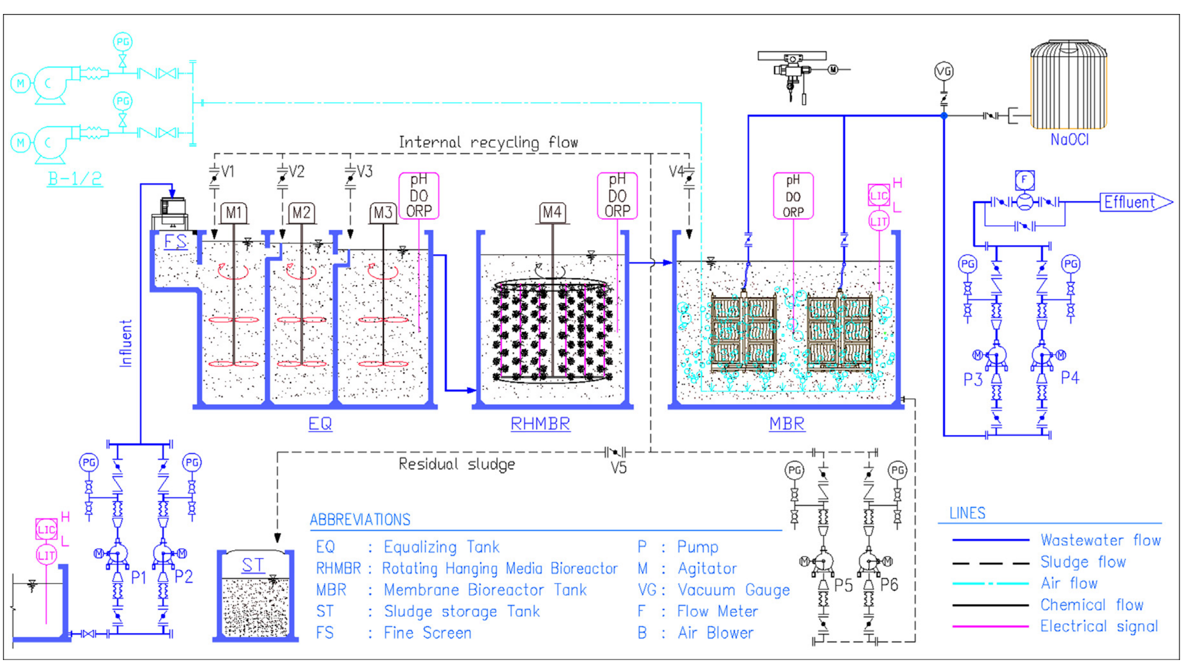

Fig. 1. Process flow of a new hybrid system.